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10. THE DETERMINATION OF PLAGIOCLASE FELDSPARS

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INTRODUCTION

The material included in this paper was brought together for the use of students in the petrographic laboratory of Harvard University and has been in use in this laboratory for a year and a half with concordant results. The curves agree closely with those given by Calkins,[1] and by Wright[2] but do not agree with those given by Iddings and other textbooks on rock minerals. As the curves by Calkins have not been published and those by Wright are not now readily accessible it was thought that this material would be of use to petrographers. Most of the data have been plotted from the stereographic projections given in the memoir of Duparc and Reinhard. In addition to the curves a discussion of the error in measurements is given. The writer is indebted to professor E. S. Larsen for his generous assistance in the preparation of this manuscript.

No attempt has been made to prepare curves for the determination of the amounts of $KAlSi_3O_8$ in solid solution as the data available are not sufficient.

Duparc and Reinhard[3] have shown that the relative amounts of $NaAlSi_3O_8$, $KAlSi_3O_8$, and $CaAl_2Si_2O_8$ in the plagioclases can be determined by locating the indicatrix with respect to the crystallographic axes by the aid of a theodolite microscope. The principal planes of the indicatrix are determined from interference figures, or by locating the optic axes; the crystallographic axes from cleavage, twinning planes, or crystal boundaries. The data obtained are then plotted on a sphere or stereographic projection using the base, (001), as the equatorial plane. For ordinary thin section work this method probably will not commend itself to petrographers on account of the time and technique involved, but it will be of value for special studies, for example in determining the optical orientation of any triclinic mineral.

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[1] Calkins, F. C., unpublished photostats.

[2] Wright, F. E., A graphical plot for use in the microscopical determination of the plagioclase feldspars, *Am. Jour. Sc.*, **36**, 540–542, (1913).

[3] Duparc, L., and Reinhard, M., La détermination des plagioclases dans les coupes minces, *Mem. Soc. de phys. et d'hist. nat. Genève*, **40**, (1924).

Duparc, L., and Reinhard, M., Les methodes de Fédorof et leur application a la détermination des plagioclases, *Bull. Suisse de Min. et Pet.*, **III**, 1924.

In the following pages not all of the methods of determining the plagioclases are discussed but only those that have been found most useful in the Harvard laboratory. The methods are described in the following order and the letter preceding the method refers to the corresponding curves on the diagrams.

A. Index of refraction.
B. Density.
C. Axial angle and optical character.
D. Extinction angles on the side pinacoid.
E. Extinction angles on the section perpendicular to the base and side pinacoid.
F. Extinction angles on the basal section.
G. Extinction angles in the zone perpendicular to the side pinacoid, (Michel Lévy statistical method).
H. Extinction angles on combined albite-Carlsbad twinned plagioclases in the zone perpendicular to the side pinacoid.
I. Extinction angles in microlites.
J. Extinction angles in sections perpendicular to the α-vibration direction.
K. Extinction angles in sections perpendicular to the β-vibration direction.
L,M. Extinction angles in sections perpendicular to the γ-vibration direction.

The extinction position referred to is in all cases the vibration direction of the ray with the lower index of refraction in the section. In crystallographically oriented sections it is denoted by α'. This position can be found easily by means of the gypsum plate. The extinction angle is measured from this vibration direction to some crystal direction, commonly the trace of the side pinacoid.

A. INDEX OF REFRACTION (See Fig. 2)

The determination of one of the three indices of refraction, (α, β, or γ), by the immersion method is one of the quickest and most reliable methods for determining the feldspars. It is not sufficient to measure a random index of refraction but one of the three principal indices should be measured. An approximate determination can commonly be made by comparing the indices of refraction of the feldspar with that of Canada balsam, or with quartz, or some other known mineral. The index of refraction of balsam is commonly near 1.539, but it may vary considerably, especially in old slides. It has been found as high as ϵ of quartz (1.554). It is therefore best to check the balsam against ω of quartz or against some other mineral with known index of refraction before using it as a standard of comparison.

B. Density (See Fig. 3)

The curve for density is approximately a straight line. The variation with composition is considerable, about 0.002 for each percent of anorthite, and, under favorable circumstances, a density measurement gives a good determination of the feldspar. However, most material is not suitable for rapid density determination on account of the difficulty of getting coarse fragments that are homogeneous, unaltered, and free from gas or other inclusions.

C. Axial Angle and Optical Character (See Fig. 3)

The optical character of the plagioclase feldspars changes sign four times, and hence can be used to divide the plagioclases into four groups and check determinations made by other methods.

CRYSTALLOGRAPHICALLY ORIENTED SECTIONS

D. Side Pinacoid (See Fig. 2)

This section can be recognized thus:

(1) Albite twin lamellae are absent.
(2) Basal cleavage planes are approximately perpendicular to this section.
(3) Zoning is conspicuous, with equal illumination of the zones at +40.5° measured from the basal cleavage.
(4) Except for the more calcic feldspars the γ-bisectrix gives a more or less uncentered figure.
(5) The geometric outline is distinctive, and commonly a parallelogram with an acute angle of 64° (fig. 1). Other faces frequently modify this outline, such as $(\bar{1}01)$, $(10\bar{1})$ and $(20\bar{1})$, $(\bar{2}01)$. $(\bar{2}01)$ makes an angle of about 98° with the base.

Even when the outlines are anhedral, the zoning, which is best shown on this face, and which follows the crystal outlines, may give the necessary clue to determine the crystallographic orientation.

Schuster defined the extinction angle as positive when the smaller extinction angle, $[\alpha' \wedge$ trace of (001)], is in the obtuse angle

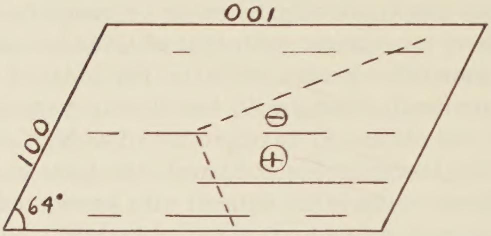

Fig. 1

between (100) and (001), and negative when it is in the acute angle.

Where zoning is present, the extinction angles on the same side of the zero position, (which is the trace of the basal cleavage), as the position of equal illimination of the zones are positive. Probably without exception in igneous rocks, the zones become more sodic toward the border, though some rhythmic recurrence of zones is common. In this section the extinction of α' and the composition can be determined for each zone.

The slope of this curve is fairly uniform for feldspars ranging from 0% to 70% anorthite, and gives a variation of about 0.7 degree for each per cent anorthite. The curve flattens for feldspars more calcic than 70% anorthite, giving a difference of about 0.25 of a degree for each per cent anorthite.

E. The Section Perpendicular to the Base and Side Pinacoid (See Fig. 2)

This section can be recognized thus:

(1) It ordinarily has a well-formed outline.

(2) The albite twins have symmetric extinction, with equal illumination of these lamellae at 0° and 45°.

(3) The suture lines of the twin and cleavage plane (010) and the cleavage plane (001) form an angle of about 86°, and the planes are perpendicular to the section. To determine whether or not a cleavage or twinning plane is perpendicular to the section focus the telescope tube up and down, and observe whether the plane remains stationary with respect to the cross-hairs or moves laterally. If it moves laterally it cannot be parallel to the line of collimation of the telescope.

(4) A negative bisectrix is more or less centered on this section in the feldspars of intermediate composition.

This extinction position, α', is measured from the trace of the albite twinning plane. The sign of the extinction is positive when it is in the acute angle formed by (001) and (010), and negative when in the obtuse angle.

This is one of the best sections for determining the composition of a plagioclase, because the variation of the extinction angle with composition is about one degree for each per cent of anorthite in the range from 0% to 35% anorthite. In feldspars more calcic than 35% anorthite the curve flattens out and gives a variation of about 0.5 of a degree for each per cent anorthite. A considerable error in the orientation gives small errors in composition for feldspar ranging from 10 to 50 per cent of anorthite, and the orientation of these sections can be determined fairly accurately. Such a method is therefore good for feldspars ranging from $Ab_{90}An_{10}$ to $Ab_{50}An_{50}$.

F. Basal Section (001) (See Fig. 2)

This section cannot be readily recognized in the thin section but as (001) is the most perfect cleavage the powdered grains used in an immersion to test the index of refraction tend to lie on this face. The most favorable grains will lie on a cleavage face and will have another cleavage face as their upper surface, and hence will be of uniform thickness and will give uniform interference colors. Step-like breaks in the cleavage are also common, giving abrupt changes in the interference colors. This face is normal to the albite twin lamellae, which will therefore have symmetric extinctions, and have equal illumination at 0° and 45°.

The curve is very flat between albite and andesine-labradorite, (50% An), a difference of one percent in anorthite giving a variation of about 0.2 of a degree. For feldspars more calcic than 50% anorthite the curve is very good, giving, for each percent difference in anorthite a variation of about 0.7 of a degree. The error due to error in orientation is relatively large, especially for feldspars ranging from $Ab_{50}An_{50}$ to $Ab_{20}An_{80}$ in composition. For such feldspars the maximum error in composition is 13% anorthite for a deviation of 10° in the orientation of the section. This method is then not of much value for determinative work unless the section be oriented very accurately.

MAXIMUM EXTINCTIONS IN CERTAIN ZONES

G. The Zone Perpendicular to the Face (010), that is Perpendicular to the Composition Plane of the Albite Twins (See Fig. 3)

This zone can be recognized easily by the fact that the twin individuals 1 and 1′ are equally illuminated at 0° and at 45°. If the orientation is perfect, the extinctions of these individuals are symmetrical and the traces of the composition planes form sharp lines. If the telescope tube be focused up and down, these lines will be found to remain stationary with respect to the cross hairs. If the section is not perpendicular to (010), the lines will appear to be blurred and to move sideways.

The extinction position, α', is measured from the albite twin plane. When the section is not perpendicular to (010) the extinction angles on the individuals 1 and 1′ will not be the same, and the mean of these two readings will then be used. The maximum extinction angle obtained in this way is then referred to curve G, which will give the composition of the feldspar.

Since the slope of the curve is steep, a deviation of 10° in orientation gives a maximum error of 2% anorthite for feldspars ranging from albite to $Ab_{30}An_{70}$, and the section can be oriented fairly accurately into the zone, this is one of the best determinative methods.

H. COMBINED ALBITE-CARLSBAD TWINNED FELDSPAR; (ZONE $\perp$ (010)) (See Fig. 4)

These sections give two sets of twin lamellae: 1, 1′; 2, and 2′. When the plane of the section is perpendicular to (010) then 1, 1′, 2, and 2′ will all have equal illumination at 0° and 45° to the planes of vibration of the nicols. At any other angle the four twin lamellae will be unequally illuminated.

The extinction angles are plotted for the zone perpendicular to (010). When such a section is found 1 and 1′, (2 and 2′), will have equal angles of extinction. When the section is not perpendicular to (010) then the four extinctions will all be unequal. The mean reading, (α'_λ trace of (010)), of 1 and 1′, and of 2 and 2′ are taken, the smallest angle is read along the vertical line of the diagram H, and the other along the isogonic curves. That is to say, the composition of the feldspar is read from a point where the horizontal line representing the smaller extinction angle meets a curved isogonic line which corresponds to the larger extinction angle.

For a plagioclase which has a composition $Ab_{80}An_{20}$ the (010) plane is one of the principal planes of the indicatrix and hence Carlsbad twinning cannot be seen in the thin section. The difference in the extinction angles of 1, 1′ and 2, 2′ increases with increasing amount of anorthite.

The two values for the extinction angles on each Carlsbad twin will give, in general, two values for the feldspar, hence this method must be supplemented by some other method such as an approximate estimate of the index of refraction, in order to tell which of the two values is the correct one.

Since a relatively small error in orientation means an appreciable error in the determination of the feldspar, these sections should be oriented accurately.

I. MICROLITES (See Fig. 2)

Curve I gives the maximum extinction angle for microlites elongated parallel to the crystallographic axis *a*. It is not possible to distinguish between positive and negative extinction angles so that, for sodic feldspars, the index of refraction test against Canada balsam must be used to determine on which side of $Ab_{70}An_{30}$ the feldspar lies.

The position of extinction, α', is measured from the direction of elongation of the microlite, and the maximum angle obtained is used to read off the composition of the feldspar on curve I.

OPTICALLY ORIENTED SECTIONS

J. SECTIONS PERPENDICULAR TO α (See Fig. 3)

This section is located by getting a centered interference figure. The extinction position used is the β–vibration direction, and the angle is measured from the trace of the (010) plane.

These sections show clearly all the twinning phenomena. The albite twin lamellae of feldspars ranging in composition from 0 to 35 percent anorthite will give symmetric extinction angles on this section. These same feldspars will have the basal cleavage approximately perpendicular, i.e. within ±10°, to this section.

This curve is good only for feldspars ranging from albite to $Ab_{50}An_{50}$, and is identical with the curve of maximum extinction angles in the zone perpendicular to (010) in the range from albite to $Ab_{65}An_{35}$.

This method gives good determinations for the sodic feldspars since the extinction angles change rapidly with change in composition, while the error in composition due to an error in orientation is small.

K. Sections Perpendicular to β (See Fig. 3)

Sections perpendicular to the β index can be recognized easily as they will show the maximum birefringence, and in convergent light a centered flash figure.

The position of extinction, α, is measured from the trace of the albite twin plane in the section.

This curve is only applicable to the calcic feldspars in which the anorthite content exceeds 35% as the curve becomes very flat for the sodic feldspars and reaches a maximum at about $Ab_{80}An_{20}$. An error of 10° in the orientation gives a maximum error of 10% anorthite for the calcic feldspars, and since this section cannot be oriented accurately this method is not of much value.

L. M. Sections Perpendicular to γ (See Fig. 3)

This section is located by getting a centered interference figure. The extinction position used is the α-vibration direction.

In the alkaline feldspars, ranging between albite and $Ab_{50}An_{50}$, the sections perpendicular to γ will not show albite twinning; the extinction position should then be measured from the trace of basal cleavage and read on curve M. These sections in feldspars which are more calcic then $Ab_{50}An_{50}$ will show the (010) twinning planes as soft lines, and extinction should be measured from them and the composition read from curve L.

ACCURACY OF DATA

Assuming that: (1) the feldspar consists only of a solid solution of albite and anorthite, and (2) the extinction curves are accurate; then the error in determination would lie in (1) the error in measuring the extinction angle, and (2) the error in orientation of the section measured.

In ordinary practice the average error in reading an extinction angle will be plus or minus one degree. This does not mean that the ordinary petrographer can not determine the extinction angle closer than this but merely that an increase in accuracy would mean such a large increase in time and technique that it is not ordinarily sought. An error of 1° in angle gives an error in composition of from 1 to 2% anorthite in the determination, an amount which is, in most cases, considerably less than the error due to imperfect orientation.

The following table gives the error in percentage of anorthite for various plagioclase feldspars caused by deviations of 10°, 20°, and 30° in orientation from the section desired, for the methods E, F, G, J, K, and H.

TABLE I

E. ERROR IN ORIENTATION FROM SECTION ⊥(001) (010)

PER CENT OF ANORTHITE	10°		20°		30°	
	Max.*	Avge.*	Max.*	Avge.*	Max.*	Avge.*
0.5% An.	7	4	10	5	12	10.5
13	1	1	2	1	5	3
20	0.5	0	3	1	8	5
25	1.5	1	2.5	1	4	2
35	2.5	1	5	4	16	9
52	4	1	5.5	4	15	8
73	8	5	15	9	20	10
97	12	10	19	15	28	19

F. ERROR IN ORIENTATION FROM BASE (001)

PER CENT OF ANORTHITE	10°		20°		30°	
	Max.*	Avge.*	Max.*	Avge.*	Max.*	Avge.*
0.5	16	11	27	19	31	21
13	5	5	13	9	20	10
20	4	2	12	6	23	12
25	1	0.5	8	3	22	11
35	7	1	7	3	22	12
52	13	6	16	5	20	10
73	13	6	22	9	28	15
97	3.5	2	74!	8	74!	13

G. ERROR IN ORIENTATION FROM THE SECTION THAT GIVES THE MAXIMUM EXTINCTION IN THE ZONE PERPENDICULAR TO (010)

PER CENT OF ANORTHITE	10°		20°		30°	
	Max.*	Avge.*	Max.*	Avge.*	Max.*	Avge.*
0.5% An.	3	1	7	3	9	7
13	0.5	0.5	1.5	1	4	3
20	0.5	0	1.5	0.5	3.5	1
35	2	1	7	4	17	10
52	2	1	7	5.5	13	11
73	2	1	10.5	4	42!	9

* Max. (avge.) means the maximum (average) error in composition expressed in percentage of anorthite.

J. Error in orientation from the section perpendicular to the α-vibration direction

PER CENT OF ANORTHITE	10°		20°		30°	
	Max.*	Avge.*	Max.*	Avge.*	Max.*	Avge.*
0.5% An.	2	1	5	3	11	7
13	0.5	0.5	1	1	4	1.5
20	0.5	0.5	2	2	8	3.5
35	1.5	0.5	8	5	28	10
52	5	4	16	11	29	12
73	44	37				

K. Error in orientation from the section perpendicular to the β-vibration direction

PER CENT OF ANORTHITE	10°		20°		30°	
	Max.*	Avge.*	Max.*	Avge.*	Max.*	Avge.*
35% An.	10	5				
52	6	4	10	7	16	10
73	8	4	16	7.5	19	12
97	10	9	19	12.5	29	20

H. Error in orientation from the zone (010). (Combined albite-Carlsbad method)

PER CENT OF ANORTHITE	10°		20°		30°	
	Max.*	Avge.*	Max.*	Avge.*	Max.*	Avge.*
35% An.	10	3	23(41)	9	29(48)	9
52	6(33)	1	22(34)	8	30(34)	14.5
73	8(14)	3.5	27	7.5	27	11

The following table gives in columns 2 and 3 the number of grains that must be examined in order that, on the average, one will have an error of orientation not greater than that listed in column 1. This error of orientation is given as the angle of deviation from the section that gives the correct extinction angle.

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* Max. (avge.) means the maximum (average) error in composition expressed in percentage of anorthite.

TABLE II

NUMBER OF RANDOM GRAINS NECESSARY

ACCURACY OF ORIENTATION	FOR ALL THE EXTINCTION CURVES EXCEPT COMBINED ALBITE-CARLSBAD TWINS	FOR THE COMBINED ALBITE-CARLSBAD METHOD
2°	1642	29
4°		14
6°	182	9
10°	65	6
20°	17	3
30°	7.5	2

For optically oriented sections, if the direction of vibration emerges on the edge of the field, then the deviation from the correct orientation will be about 30° for the general types of petrographic microscopes. If the vibration direction emerges about two-thirds of the distance from the center to the edge of the field then the deviation will be between 15° and 20°.

Assuming now that (1) an average thin section has a diameter of 15 millimeters and that plagioclase feldspar makes up half the slide, and (2) that the best feldspar section in the slide for a certain method of determination, (excluding the method for combined albite-Carlsbad twinning), is chosen for the determination; then the average deviation or error in orientation from the section desired of the best section in the slide, i.e. the statistical minimum deviation in orientation, is given in the following table for various grain sizes which correspond to medium grained rocks.

TABLE III

DIAMETER OF GRAIN IN MILLIMETERS	ERROR IN ORIENTATION OF THE BEST SECTION IN THE SLIDE, GIVEN AS THE DEVIATION FROM THE SECTION TO WHICH THE TRUE ANGLE OF EXTINCTION CORRESPONDS
1	8°
2	15°
3	23°
4	31°
5	35°

Thus when using, for example, exclusively the Michel Lévy statistical method on medium-grained rocks the best sections will have an error in orientation of about 20°. The following table IV taken from table I gives the error in composition to be expected from such a section, and since this is one of the best sections for determinative work the other methods will, in general, have a larger error in composition, the values for which can be obtained from Table I.

TABLE IV

Feldspar in per cent of anorthite	Maximum error in per cent of anorthite, due to orientation ± reading	Average error in per cent of anorthite
0.5	7 ±2	3 ±2
13	1.5±1	1 ±1
20	1.5±0.5	0.5±0.5
25	7 ±0.5	4 ±0.5
35	7 ±1.5	5.5±1.5
52	10.5±2	4 ±2

This error in orientation will, of course, be decreased when several methods are used conjointly and the best section of several methods is utilized.

The error in orientation from the zone (010), (the method for combined albite-Carlsbad twinning), assuming that all the feldspar grains display combined albite-Carlsbad twinning and that the best of the sections is chosen, is given in column 2 of the following table for various grain sizes, corresponding to the medium-grained rocks, and which are listed in column 1.

TABLE V

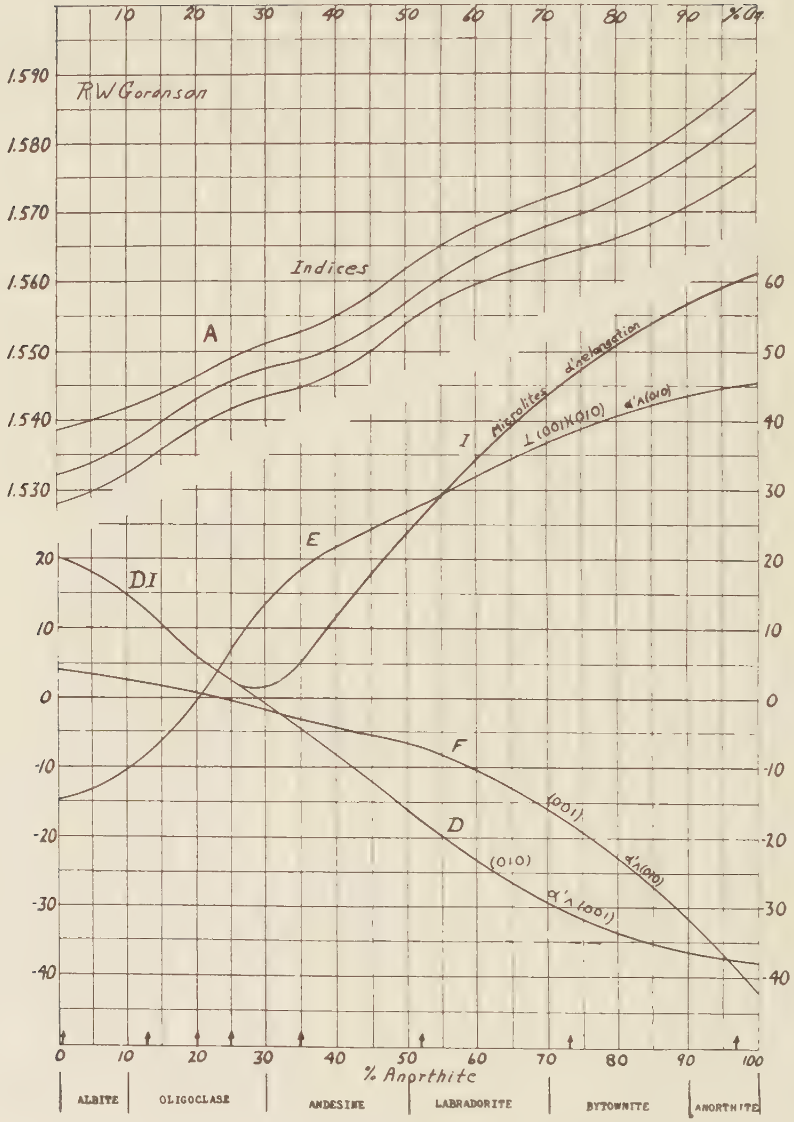
Diameter of grain in millimeters	Error in orientation of the best section, i.e. deviation from the zone perpendicular to (010)
1	0
2	2°
3	5°
4	8°
5	13°

Thus the error in orientation for this zone will be in general about 5° or less, and the best section can be found easily, (see the discussion on this method). This is the reason that the method has any determinative value, since an error on 10° in orientation means an error in composition of from 6 to 10% anorthite.

By the ordinary rapid immersion method, using liquids calibrated to 0.001 and 0.01 apart, the indices of refraction can be measured with a probable error of less than ± 0.003. An error of ± 0.003 in the β index means an error in composition of from 4 to 9% anorthite. To be sure that the error in composition is less than 5% the index must be determined to ± 0.001.

One occasionally finds that an author has stated the composition of a feldspar determined by these methods to a tenth of one percent anorthite which is ridiculous since, in ordinary practice, the error in determining the composition is about 5% or more of anorthite.

If care is used in choosing the best section in the slide and in measuring the extinction angles, and if several of the best methods are used conjointly, one should be able to bring the error in composition to within 5 per cent anorthite. That is to say, if these precautions are observed, the composition of the feldspar can be stated to ± 5% anorthite with a fair amount of certainty.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1.590
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R W Goranson
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E
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α'∧(001)
60
50
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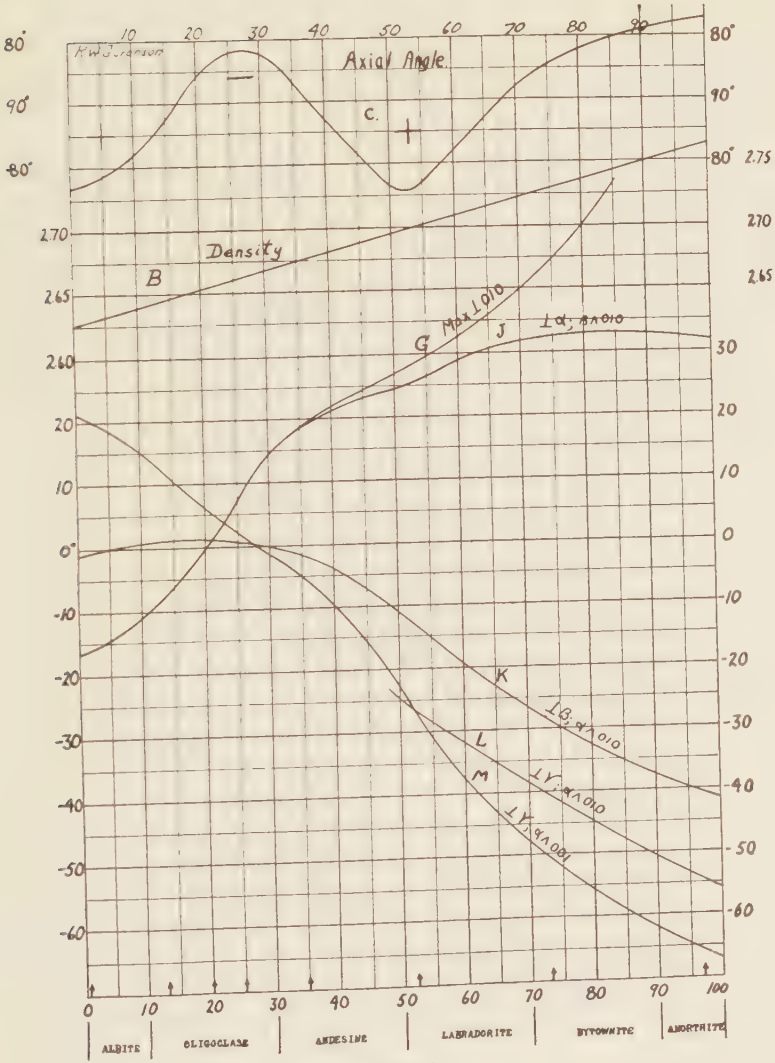
OLIGOCLASE
ANDESINE
LABRADORITE
BYTOWNITE
ANORTHITE

FIG. 2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20
30
40
50
60
70
80
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80°
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Axial Angle
C.
−
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90°
80°
2.75
2.70
2.65
2.70
2.65
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Density
B
G
Max ⊥ 010
J
⊥α; β∧010
30
20
10
0
-10
-20
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-30
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-60
K
⊥β; α∧010
L
⊥γ; α∧010
M
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ALBITE
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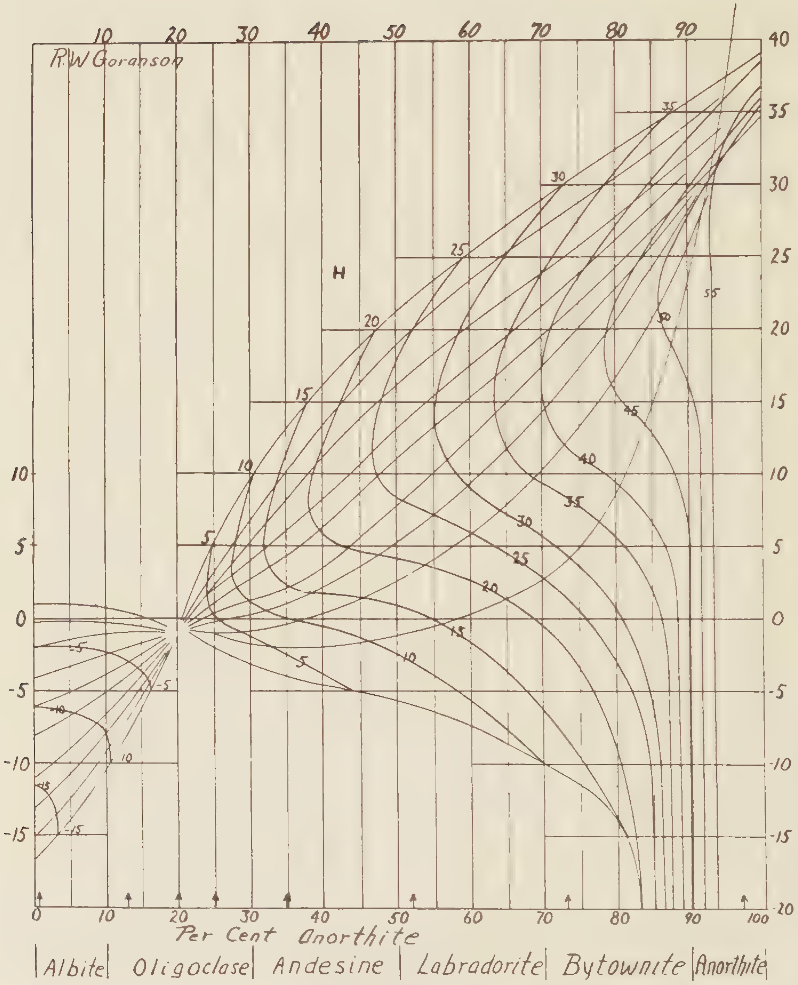
ANORTHITE

FIG. 3


R.W Goranson
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-5
-10
-15
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50
60
70
80
90
100
Per Cent Anorthite
Albite
Oligoclase
Andesine
Labradorite
Bytownite
Anorthite

FIG. 4

URANIUM MINERALS FROM LUSK, WYOMING

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U. S. Bureau of Mines, and W. T. SCHALLER, *U. S. Geological Survey*

INTRODUCTION

The occurrence of uranium minerals at Lusk, Wyoming, was noted in 1919 by Lind and Davis[1] who tentatively proposed the name lambertite for one of the uranium minerals present, which they thought might be UO_3. This mineral has been definitely identified as uranophane and as the only other uranium mineral present showed no properties different from those of pitchblende, the name lambertite is found inapplicable to any uranium mineral yet found at Lusk. These minerals were studied when all three authors of this paper were members of the Geological Survey and as the first two have now left, it seems best to place on record the results obtained, even though it is recognized that a more detailed description of the uranium minerals could be given.

OCCURRENCE (F. L. H.)

In 1918 uranium minerals were discovered in a hill on the north of Lusk, Wyoming, a locality far removed from other known uranium deposits and, indeed, from any other important mineral deposit. The eminence, known as Silver Hill, is one of a small range of hills and rises about 200 feet (barometric measurement) above Niobrara Creek which has been cut through the range. The hills have here a nearly north-south trend, and have been formed by the doming of the rocks. The core of Silver Hill is formed by vertical eroded schists, apparently the same as those at Sunrise and Hartville, Wyoming, and over them lies unconformably a somewhat conglomeratic quartzite. These are evidently the rocks which were designated by Smith and Darton[2] as respectively, the Whalen group (Algonkian) and a member of the Guernsey formation (Mississippian). Pegmatites intruded the schists before the deposition of the quartzite, were earlier, and had no connection with the deposits of the uranium.

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[1] Lind, S. C., and Davis, C. W., A new deposit of uranium ore: *Science*, N. S., **49**, 441–443, May 9, 1919.

[2] Smith, W. S. T., and Darton, N. H., The Hartville folio. *U. S. Geol. Survey, Geologic Atlas* **91**, 1903.

Silver Hill is cut lengthwise by a thrust fault having a dip of about 60° E. and a vertical movement of about 100 feet. The fault is probably due to the folding which formed the ridge, of which Silver Hill is near the northeastern end, and which trends southwesterly through Hartville. This is apparently an old line of disturbance, and at Hartville are great iron and copper deposits which were formed in the Algonkian rocks and eroded with them. The latest uplift along the ridge is said by Darton[3] to have taken place "toward or at the close of the Cretaceous period." The deposition of the ore at Lusk was probably associated with this movement but followed it, for the gouge along the fault prevented deposition on the hanging wall side.

At Lusk, in the quartzite on the under side of the fault, silver and copper had been mined in a small way some years ago. The primary minerals present are chalcocite and pitchblende, calcite (the principal introduced mineral), and probably some quartz. Secondary minerals present are: azurite, malachite, chrysocolla, uranophane partly in radiating tufts of tiny crystals, and a few very small masses of a red mineral not tested but almost surely gummite.

The solutions from which the minerals were deposited followed cracks and spread from the cracks into the quartzite, replacing its cement. That this took place after the silicification of the original sandstone is shown by the fact that many small cracks in the quartzite are unhealed. If solidification of the original sandstone had taken place after the cracking most if not all of the cracks would have been filled with quartz. From the manner of deposition it follows that the original uranium mineral or minerals were scattered between the sand grains, mixed with other minerals, so that pure material has not been found. Had the ore bearing solutions flowed longer or been more plentiful, so that the sand grains too were replaced, as in the lead deposits of the Coeur d'Alene district or some of the Andean tin deposits, larger masses probably would have been formed.

The gouge along the fault has prevented the deposition of the minerals on the upper side, and no uranium has been found in the schists with the exception of a little at the very top.

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[3] *Loc. cit.*, p. 5.

IDENTITY OF LAMBERTITE WITH URANOPHANE (E.S.L. & W.T.S.)

The material to which the name of lambertite was given, had been previously referred to E. S. Larsen for optical examination and identification and had been reported to be uranophane. Lind and Davis, however, thought that their chemical work indicated a new mineral in spite of the identification reported. They say:—

"The chemical evidence of the writers on material not so pure as could be desired (about 80 per cent pure) indicates that the soluble bases and acids account for each other without reference to the uranium oxide at all. This was taken to indicate the existence of a free higher oxide, probably UO_3."

The material furnished by Lind and Davis sufficiently identified the "lambertite" as the well known mineral uranophane, and study of additional material collected by Frank L. Hess has fully confirmed this identification. It therefore seems advisable to place on record the facts obtained and to prevent, as far as possible, the introduction of the name "lambertite" into mineralogical literature.

The optical properties of the yellow uranium mineral (the so-called lambertite) from Lusk, Wyoming, sent in by Dr. Lind, are as follows: (determined by E. S. Larsen): Optically negative, with a slight varying optical angle, $2V_{Li} = 32°$ to $42°$, $2V_{Na} = 37°$ to $45°$.

Strong dispersion, $\rho < \nu$. The acute bisectrix, X, is sensibly normal to the flat face, and Z is parallel to the elongation. The optical relations indicate orthorhombic symmetry. The indices of refraction measured by the immersion method are: $\alpha = 1.642$, nearly colorless; $\beta = 1.665$, canary yellow, a little paler than γ; $\gamma = 1.672$, canary yellow. These values are identical, within the limits of error of measurement, with the indices of uranophane from other localities, as the following table shows, the last three sets of values being taken from Larsen's mineral tables.[4]

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[4] Larsen, E. S., The microscopic determination of the non-opaque minerals: *U. S. Geol. Survey, Bull.* **679**, 149–150 (1921).

COMPARISON OF OPTICAL PROPERTIES OF URANIUM MINERAL (THE SO-CALLED LAMBERTITE) FROM LUSK, WYOMING, WITH THOSE OF URANOPHANE FROM THREE OTHER LOCALITIES

OPTICAL PROPERTIES	MINERAL FROM LUSK, WYOMING (LAMBERTITE)	URANOPHANE		
		SILESIA	SCHNEEBERG, SAXONY	NEUSTADT, SAXONY
α	1.642	1.643	1.645	1.642
β	1.665	1.667	1.665	1.666
γ	1.672	1.670	1.667	1.670
Opt. char.	Negative	Negative	Negative	Negative
2V	37° to 45° (Na)	Small	32° (Na)	Small
Dispersion	Strong	Marked	Extreme	Marked
Optical orientation	Elong. of fibers = Z X ⊥ flat face	Elong. of fibers = Z	Elong. of needles = Z X ⊥ flat face	Elong. of fibers = Z
Pleochroism	α nearly colorless β pale canary yellow γ canary yellow		α nearly colorless β pale canary yellow γ canary yellow	

Several specimens of a yellow uranium mineral from Lusk were collected by Frank L. Hess and comparison of its optical properties (determined by W. T. Schaller) with those (determined by E. S. Larsen) on the "lambertite" furnished by Lind and Davis, shows them to be the same mineral.

OPTICAL PROPERTIES OF MINERAL FROM LUSK COLLECTED BY F. L. HESS AND COMPARED WITH THOSE OF "LAMBERTITE"

	URANOPHANE COLLECTED BY F. L. HESS	"LAMBERTITE" FURNISHED BY LIND AND DAVIS
	Orthorhombic	Orthorhombic
α	1.643	1.642
β	1.665	1.665
γ	1.670	1.672
Elongation	Z	Z
Dispersion	Strong $\rho<v$	Strong $\rho<v$
Sign	Negative	Negative

The mineral collected by Hess has a moderate axial angle (2E), the axial plane is parallel to the elongation, B_{xa} (X) is normal to the flat face, and good cleavages are present in the prism zone.

There can be no question about the identity of the two minerals, whose optical properties are similar and the chemical analysis given later, shows one of them to have the composition of uranophane.

The rosettes of yellow crystals of uranophane on the specimen collected by Hess reach a diameter of about half a centimeter. The individual prismatic crystals are a millimeter or so long and about one-fifth as thick. A hand lens inspection suggested that many of the crystals would yield good reflections on the goniometer but it was soon seen that no good measurements could be obtained. No terminal faces could be definitely established for they were considerably rounded and dull and gave no reflections. Of the faces in the prism zone only the cleavage ones gave good single reflections, all the others being faint, multiple, and very poor. Several of the prismatic crystals, when measured on the goniometer gave values for faces in the prism zone and the values obtained on three such crystals are shown below. The broad faces (perhaps all cleavage faces on the crystals measured) are taken as the macropinacoid *a* (100) and the angular measurements taken against this face. All the other faces in the prism zone are narrow and vertically striated so that the relative size of the brachypinacoid *b* (010) as compared with those of the very close lying brachyprisms could not be determined.

The disposition of the faces on the first crystal suggests triclinic symmetry; those on the other two crystals, however, show that the distribution of the prism faces is very irregular and no importance can be attached to it. In fact the sets of crystal measurements yield no information as to their symmetry. It has been established though, from the results of the optical examination, that the mineral is orthorhombic and the crystal measurements in part verify this conclusion. The crystals have a face (the brachypinacoid) at right angles to the large (cleavage) face present on all crystals. This has been measured to be 90°44′, 89°10′, 89°45′, 90°15′ and 89°35′ inclined thereto, a very close approximation to 90°, considering the vary faint and striated reflections obtained from the crystal faces.

The interpretation of the prism faces is considerably in doubt; it is to be noted though that a considerable consistency is present in the angles, the ϕ angle falling into several distinct groups, as follows (the ϕ angle being measured from the branchypinacoid):

2°28′ on crystal 1.
2°55′ “ 3.
3°33′ “ 3.
2°02′ “ 3.
3°04′ “ 3.
Av. = 2°48′

4°42′ on crystal 2.
4°39′ “ 3.
4°45′ “ 3.
Av. = 4°42′

6°04′ on crystal 1.
6°38′ “ 1.
6°46′ “ 2.
6°14′ “ 3.
Av. 6°26′

10°53′ “ 1.
9°54′ “ 1.
9°17′ “ 2.
8°45′ “ 2.
8°15′ “ 3.
Av. = 9°25′

14°09′ on crystal 2.
14°42′ “ 3.
Av. = 14°26′

That these angles are not altogether fortuitous but are related in some way, is evident by considering their cotangents which rather closely form the normal series N_3, as shown below.

COTANGENTS OF ϕ ANGLES OF PRISMS, FORMING NORMAL SERIES

MEASURED ANGLE	MEASURED COTANGENT	CALCULATED COTANGENT	NORMAL SERIES	CALCULATED ANGLE
2°48′	20.45	18.09	3	3°10′
4°42′	12.16	12.06	2	4°44′
6°26′	8.87	9.05	3/2	6°19′
9°25′	6.03	6.03	1	9°25′
14°26′	3.89	4.02	2/3	13°58′
		3.02	1/3	18°21′
		2.01	1/3	26°27′

The last two members, ½ and ⅓, of the normal series, are missing but the other calculated angles (taking the form whose ϕ angle is 9°25′ as unity) show a fair agreement with the measured angles. The crystallography of uranophane, however, is so inadequately known, that these faces can not definitely be correlated with those of other crystals of the mineral. Although no terminal faces could be measured on the reflecting goniometer, microscopic observation of the material shows abundant terminated crystals. Some of the crystals show the traces of two symmetrical planes inclined about 90° to each other and inclined (as measured) from 42½° to 44½° to the elongation. The average of 7 measurements of this inclination is 43°. On other crystals the trace of a third plane normal to the elongation was observed. All these crystals or cleavage pieces showed parallel extinction.

The observations of Pjatnitsky[5] on the crystal form of this mineral as triclinic could not be verified on the material from Lusk.

A chemical analysis (by W.T.S.) made on a small quantity of the yellow mineral, mixed with calcite, gave the results shown below. Microscopic examination of the sample analyzed showed it to be about ⅓ calcite and ⅔ of the yellow mineral. The analysis of the sample is shown below.

ANALYSIS OF MIXTURE OF CALCITE AND URANOPHANE FROM LUSK, WYOMING

ANALYSIS		CALCUL. FOR 67.7% URANOPHANE 30.3% CALCITE 2.1% QUARTZ	ANALYSIS WITH CALCITE AND QUARTZ DEDUCTED
UO_3	45.5	45.4	67.2
CaO	20.9	21.4	6.5
SiO_2 (sol.)	9.4	9.4	13.9
H_2O+CO_2(ign.)	22.2	21.8	(H_2O) 12.6
Quartz (insol.)	2.1	2.1	
	100.1	100.1	100.2

The identity of the yellow mineral, which when mixed with other minerals has shades of brown, black, and green, from Lusk, as uranophane, can not be doubted and the name lambertite should be stricken from the list of mineral names.

PITCHBLENDE (W.T.S.)

The black uranium bearing material seems to be of infiltration and replacement origin and is itself considerably replaced by its oxidation products as well as by secondary copper minerals. It is massive, opaque, and shows no distinct individualized properties. It was hand picked as far as possible and after being crushed to 100 mesh was then repeatedly concentrated by heavy solution (methylene iodide). Several grams of material were finally obtained which seemed to represent as pure a product as could be gotten under the circumstances. It was, however, very easy to demonstrate on polished specimens of quartzite containing the black mineral the presence of quartz, calcite, chalcocite, and an unidentified metallic mineral whiter than chalcocite, uranophane ("lambertite"), chrysocolla, and limonite. Metallic copper seemed to be present. It is very likely that other secondary minerals (copper carbonates, copper oxide, various secondary uranium minerals, etc.) were also present.

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[5] Pjatnitsky, P., Ueber die Krystallform des Uranotil: *Z. Kryst. Min.*, **21**, 74–85 (1893).

The analysis of the sample is given below.

Analysis of Impure Sample of Pitchblende from Lusk, Wyoming

		Percentage	Source
S	In insoluble portion	0.71	Chiefly as chalcocite
Cu		2.69	
Quartz		18.02	Quartz
SiO_2 soluble		7.64	Uranophane and chrysocolla
CuO		7.23	Chrysocolla and other secondary copper minerals
CaO		8.91	Uranophane and calcite
MgO		0.46	Unknown
Fe_2O_3 total		0.63	Limonite
Al_2O_3		2.87	Unknown
BaO		0.15	Unknown
K_2O		0.35	Determination probably high
Na_2O		0.69	
P_2O_5		0.45	Unknown
CO_2		5.42	Calcite
PbO		0.23	Unknown, probably pitchblende
UO_2		18.64	Pitchblende
UO_3		17.06	
H_2O-		2.72	Secondary chrysocolla and uranophane, and probably some moisture
H_2O+		5.54	
		100.41	

The determination of PbO was made on a half gram sample and cannot be considered very accurate. Traces of zinc and of arsenic were noted but no reactions for the presence of sulphates, rare earths, or vanadium were obtained. Elements not recorded were not tested for. It is impossible to allocate the different bases as the form of combination is not known. The copper, for example, may be present as any part of the mineral association—copper, tenorite, cuprite, azurite, malachite, chrysocolla, and still other compounds. Moreover, it is not known in what combination the magnesia, alumina (determined by phenylhydrazine), or phosphoric acid, are present. Neither is it definitely known where the small quantity of lead belongs. The simplest interpretation of the analysis is to consider the two oxides of uranium to be the essential constituents of the black mineral. Not all the UO_3 belongs to this black mineral, for secondary uranium compounds (uranophane, etc.) are present and a small quantity of UO_3 must be ascribed to them. This leaves, as components of the black mineral, UO_2 with a slightly smaller quantity of UO_3, and the mineral would then be pitchblende. The ready solubility of the black mineral in HCl might seem to refute the conclusion that it is pitchblende, this mineral being considered insoluble in HCl. Tests made on the solubility of pitchblendes from different localities however have shown that some are much more soluble in HCl than is generally recognized. One from Colorado, when tested, was found to be completely soluble in HCl if left standing on the steam bath for a day.

In conclusion, then, no evidence could be found which would refute the suggestion that the UO_2 and UO_3 in the black material from Lusk, Wyoming, are present essentially as pitchblende, and while at present it seems impossible to prove definitely its identity, the reference to pitchblende seems fully warranted.

AGE OF THE PITCHBLENDE (F.L.H.)

The known geology and the analysis of the pitchblende give an opportunity to adduce another bit of evidence concerning the age of the earth as shown by atomic disintegration. The theory that the age of uranium minerals may be determined by the quantity of lead present in the mineral is well known. It is based on the now universally accepted theory that uranium-lead having an atomic weight of 206, and which is an isotope of ordinary lead, is a product of the disintegration of uranium.

Based on the percentages of Pb and U as calculated from the analysis, the age of the mineral may be calculated. Accepting tentatively the formula

$$\frac{\text{Pb}}{\text{U}}.79.10^8 = \text{years},$$

then the age of the mineral is

$$\frac{.21}{30.63}.79.10^8 = 54{,}000{,}000 \text{ years.}$$

This is a greater time than ordinarily has been considered to have elapsed since late Cretaceous time, and immediately raises the suspicion that possibly common lead may be mixed with the uranium lead. No lead minerals were recognized in a careful microscopic examination of the material, and it is believed that none were present. It is unfortunate that sufficient material was not at hand to separate the quantity of lead necessary for an atomic weight determination, and thus definitely settle the question. Such determinations are important when age calculations are to be based on analyses. However, it seems probable that our ideas of geologic time must be lengthened rather than shortened.

DIRECTIONAL FACTORS IN RADIO CRYSTAL DETECTORS

A. C. Hawkins, *Rochester University*

During experimentation with the various crystal detectors enumerated by Wherry in his recent excellent article,[1] it occurred to the writer that perhaps there might be some directional factor involved in the excellence of certain crystal detectors, i.e., that such detectors might transmit radio waves more readily in one or more directions than in others, said directions depending upon the molecular network of the crystals of the detectors concerned. It was therefore decided, as the simplest convenient way of trying out the idea, to test as many natural crystals as possible to determine whether certain crystallographic faces or series of faces gave better or poorer rendition on the crystal set when the "cat's whisker" was applied to them. Very good results were obtained from crystals of some of the better detectors when they were used without mounting, simply resting on a face parallel to that upon which the "cat's whisker" was brought to bear. Among the galena crystals tried, those from Mineral Point, Wisconsin, gave excellent results, the strength and clearness of rendition being very much better on all the octahedral faces of the natural crystal than on the cubic ones. The best pyrite crystals that were tried came from near Winkelman, Arizona, showing cube, octahedron, dodecahedron, three pyritohedrons and one or more diploids. These and pyrites from some other localities were tried, with the result that the octahedral faces were found to give strongest and clearest results, the cube faces being next best, and the pyritohedrons and diploids rather inferior. Roughness of the octahedral faces, nevertheless, may play an important part in the results obtained. It is hoped that following this suggestion, someone will find an opportunity to test a number of oriented sections of the better radio detectors, in order to demonstrate the truth or falsity of the ideas herein set forth.

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[1] *Am. Mineral.*, **10**, 28–31 (1925).

NOTES ON PYRITE AND CELESTITE FROM ROCHESTER, NEW YORK

A. C. Hawkins, *Rochester University*

A short article contributed some little time ago to this journal by the present writer[1] is supplemented by the following brief notes.

During 1925, in the town of Brighton, near the eastern boundary of the City of Rochester, pyrite crystals in the form of the simple dodecahedron, with an occasional tiny octahedral modification, have been discovered. They are oxidized to a nearly black color, but are fresh within. The largest of them are not more than a millimeter in diameter. Their edges are slightly raised, as in some sphalerite crystals, and they are perched upon crystals of yellow dolomite associated with scalenohedrons of calcite and tiny marcasite crystals. The occurrence is in loose boulders of the Lockport dolomite, or the Guelph member thereof.

Celestite crystals from the town of Brighton, 3×5 centimeters in size, and white in color, consist of a simple combination of the unit prism (*m*), and the pinacoid (*a*). Small crystals of this type show pyramidal terminations, too deeply etched for measurement. This celestite is associated with yellow dolomite, and occasionally with fluorite which is colorless or light blue. A celestite crystal from the barge canal in the vicinity of the Scottsville road at the extreme western edge of the city, is yellow in color, and associated with a very deep purple fluorite crystal and dolomite. This celestite crystal is about 2.5 centimeters in diameter and is strongly tabular on the base, with a shape like many wulfenite crystals. Its forms are as follows: *c*(001), *m*(110), *b*(010), *d*(101), *o*(011), ϑ(124). Its yellow color and unusual habit are tentatively attributed by the present author to the presence of petroleum residues, which are found at times in the cavities in dolomite and in crystals of the various minerals themselves. Both of these occurrences of celestite are probably in the Guelph member of the Lockport dolomite.

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, April 1, 1926

A stated meeting of the Philadelphia Mineralogical Society was held on the above date, with President Vaux in the chair. Attendance, twenty-six members and sixteen visitors.

Mr. Fred Dippel, of Philadelphia, was elected to junior membership. The secretary reported that Mr. M. L. Jandorf, of York, Pa., has asked the society's aid in disposing of his mineral collection.

The speaker of the evening was Dr. James A. Branegan of Philadelphia, who addressed the society on *Economic Mineralogy among the Indians of Prehistoric America*. The Indians of the eastern United States were well acquainted with the physical properties of many common minerals and rocks. In the preparation of their various artifices they always carefully selected their stones for the purposes to which they were best adapted.

For knives, arrows, scrapers, and sharp-edged tools the Indians used jasper, quartz, and other forms of silica, and obsidian. These materials fracture easily to a sharp cutting edge, but are brittle, and hence were never used for tools subject to shock. For implements of the latter class, which include axes, mortars and pestles, etc., granite diorite and other igneous rocks were used. These are tough and not easily broken but had to be worked to shape by tedious hammering with another stone. The soft rocks such as slate and serpentine were used for ornaments of various kinds because they could be easily worked and polished. Cooking utensils were made of soapstone and serpentine because of the heat resistance of these rocks.

The Indians made their arrowheads by first cracking the solid jasper with the aid of fire and cold water then breaking the boulders into rough chips which they carried home and finished at their leisure by chipping the edges with a dry bone. The war arrows were made with barbs the hunting arrows without them.

The Indians of the Susquehanna valley were found to be burning coal by the Jesuit missionaries in 1660.

The lecture was illustrated by a collection of arrowheads, axes, hoes, bannerstones and other Indian implements and weapons. The speaker surprised his audience by demonstrating how firmly an axe-head of stone could be fastened to its handle with nothing more than a piece of rawhide.

The meeting adjourned with a rising vote of thanks to Dr. Branegan for his interesting address.

Horace R. Blank, *Secretary*

NEW MINERAL NAMES

AMPHIBOLES

G. Murgoci: Sur la Classification des Amphiboles bleues et de certaines hornblendes. *Compt. Rend.* **175**, 426–429 (1922).

Barroisite

Glaucophane passing to hornblende. Color dark green wich c = bluish green or greenish blue; b = green, sometimes bluish or violet; a = gray or yellow. $Z : c = 12° - 15°$. 2 V variable but very small sometimes uniaxial or almost isotropic. Plane of the optic axes sometimes across prism.

Laneite

A variety of barkevikite that is uniaxial and with the plane of the optic axes transverse.

Weinschenkite

A magnesic-calcic amphibole. Color brownish black. Poor in FeO but rich in sesquioxides and water.

Rimpylite

Color green or brown. Very rich in sesquioxides, poor in magnesia.

W. F. Foshag

Beidellite

Esper S. Larsen and Edgar T. Wherry: Beidellite, a new mineral name· *Jour. Wash. Acad. Sci.*, **15**, 465–466 (1925). Also Clarence S. Ross and Earl V· Shannon: The chemical and optical properties of beidellite. *Ibid.*, 467–468 (1925)· Originally described by Larsen and Wherry: Leverrierite from Colorado, *Jour· Wash. Acad. Sci.*, **7**, 208 (1917).

Name: From the locality, *Beidell*, Colorado.

Chemical Composition: A hydrous silicate of aluminum. $Al_2O_3.3SiO_2.X H_2O$ (X is usually 4). (Analysis of the type mineral given in original description.)

Crystallographic Properties: Probably orthorhombic. Crystals are thin plates.

Physical and Optical Properties: Color white reddish or brownish gray. Lustre waxy to vitreous. n variable, $\alpha = 1.494$, $\beta = \gamma = 1.536$. Biaxial with $2 E = 16° - 24°$ and $2 V = 9° - 16°$.

Occurrence: Found as a clay gouge made up of minute micaceous plates at Beidell, Colorado.

Discussion: The mineral described as a gouge from the Black Jack Vein, Carson District, Owyhee Company, Idaho by Shannon;[1] as leverrierite from Manhattan by H. G. Ferguson;[2] as a devitrified volcanic glass by Miser and Ross;[3] as an alteration of zeolities by Shannon;[4] and as a schist forming mineral by Corbett;[5] are all to be classed as beidellite.

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[1] *Am. Mineral.*, **10**, 34–36 (1925).

[1] *Proc. U. S. Nat. Museum*, **62**, art. 15 (1922).

[2] *Economic Geology*, **16**, 1 (1921).

[3] *Amer. Jour. Sci.*, **9**, 119 (1925).

[4] *Amer. Mineral.*, **10**, 159 (1925).

[5] *Amer. Jour. Sci.*, **10**, 247 (1925).

(Except for the somewhat lower water content and concomitant higher indices of refraction the beidellite is similar to anauxite. cf. *Amer. Mineralogist*, **10,** 201 (1925). The toad stone clays of Derbyshire, England, described by Cecil S. Gannett[6] apparently also belong here. Abstr.) W.F.F.

Iron Beidellite

Clarence S. Ross and Earl V. Shannon, *Jour. Wash. Acad. Sci.*, **15,** 467–468 (1925).

Name: In reference to its composition, an iron bearing beidellite.

A mineral similar to beidellite but carrying 18.54% Fe_2O_3. The name was intended to be ferriferous beidellite. W.F.F.

Pufahlite

Ahlfeld: Pufahlit ein Neues Sulfostannate (Pufahlite a new sulphostannate). (Preliminary paper). *Metall und Erz.*, **22,** 135–136 (1925).

Name: In honor of Dr. Otto Pufahl.

Chemical Composition: A sulfostannate of lead. Analysis: Sn 41.9, Pb 37.4, Zn. 6.3, S 13.5, Ag. 208 g./t.

Physical Properties: Color black, lustre metallic, streak black. Cleavage perfect. Hd. 2–3. Sp. Gr. 5.4. Feel smooth. Plates flexible.

Occurrence: Ichocollo Mine, 17 km. N.E. of Pasña, Bolivia, associated with cassiterite, galena and sphalerite.

Discussion: This mineral is without doubt teallite. Specimens from this mine have all the properties of teallite. (Abstr.) W.F.F.

Droogmansite

H. Buttgenbach: La Droogmansite, nouvelle espèce Minérale. (Droogmansite, a new mineral species) *Ann. Soc. Geol. Belg.*, **48,** 1–3 (1925).

Name: In honor of Hubert *Droogmans*, president of the Comite Spécial du Katanga.

Chemical Composition: Not given. Contains no phosphorus. Soluble in HCl.

Crystallographic Properties: Habit acicular, tabular.

Physical and Optical Properties: Color orange yellow, non-pleochroic. Weakly birefringent, extinction parallel, elongation negative, acute bisectrix normal to the lamellae. Biaxial negative, dispersion strong. n greater than 1.74.

Occurrence: Found as radiated balls less than ½ mm. in size on a specimen of sklowdowskite with curite and cobalt wad. W.F.F.

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[6] *Mineralog. Mag.*, **20,** 151 (1923).